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SCIENCE FOR POLICY BRIEF

# On the risk of reversal of carbon farming projects

2026

## HIGHLIGHTS

- The The Carbon Removal and Carbon Farming (CRCF) regulation (EU)2024/3012 aims at supporting suistainable practices that increase climate change mitigation by developing a voluntary carbon (C) market for the EU.
- Carbon farming activities can contribute to land resilience and climate change mitigation potential.
- The contribution to climate mitigation depends on the ability to ensure the permanence and integrity of the carbon removals.
- The concept of a buffer pool, a reserve of sequestered carbon units set aside to account for potential risks of reversals, has been introduced in the CRCF.
- We provide practical recommendations for the development of a science-based risk assessment and buffer pool quantification.
- We provide a pan European estimate of the buffer pool for activities related to agriculture, soil organic carbon and afforestation.

## Introduction

### Problem statement

As the European Union (EU) accelerates its transition to a climate-neutral economy under the Climate Law (2021/1119), the European Commission adopted the Carbon Removal and Carbon Farming (CRCF) Regulation (2024/3012), which aims  promoting sustainable land use, land resilience and climate mitigation, including reducing greenhouse gas emissions from agricultural soils, supporting the development of a voluntary carbon market at EU scale. The initiative aims to incentivize land managers to adopt climate-friendly practices, such as afforestation, peatland-rewetting, and agricultural practices known to be beneficial for carbon sequestration and storage into the soil and biomass. However, the success of this initiative depends on the ability to ensure the permanence and integrity of the CRCF units generated by these activities. A key challenge in achieving this goal is the risk of reversals or losses of carbon due to unforeseen events such as natural disasters, wildfires, windthrown, or disease outbreaks, which are increasing in frequency and intensity (for example, Migliavacca et al., 2025). To address this challenge, liability mechanism concepts are to be used, one of the most common being used is the buffer pool, which involves setting aside a reserve of carbon units to account for potential risks.

#### Box 1 - Definitions

- **Buffer pool,** a reserve of carbon units set aside to account for potential reversals or losses of carbon in a project.
- **Carbon unit** represents one tonne of carbon dioxide equivalent (t $CO_{2\text{-}eq}$) that is removed from the atmosphere or avoided through a carbon farming project, which is verified and certified in accordance with the CRCF regulation.
- **Reversal risk** is the risk that the removals or emissions reductions achieved by a carbon farming project are reversed, either partially or totally, due to natural or human-induced events, such as fires, pests, diseases, changes in land use or management practices, or other factors that may affect the carbon stocks or greenhouse gas emissions of the project.
- **Natural disturbance**, an event or process that alters the natural environment, including but not limited to fires, windthrows, insect outbreaks, and other non-anthropogenic events that can impact forest ecosystems. The definition is constrained by the disturbances considered in the forest disturbance products.
- **Disturbance risk**, the likelihood of a natural disturbance occurring in a given area and for a given forest type.
- **Disturbance regime indicators:**
  - Disturbance return period: the average time between natural disturbance events in a given area and here derived from satellite observations.
  - Disturbance intensity: the average percentage of biomass lost due to natural disturbances in a given area.
- **Monitoring period** is the period during which the storage of carbon is monitored. When the monitoring period is longer than the activity period, it is necessary to guarantee the validity of the units issued during the activity period.

A buffer (see Box 1 for definitions) is a mechanism to ensure the integrity and permanence of carbon units issued by a project. The buffer pool is typically a percentage of the total units issued through an activity by an operator (or a group of operators), and it is used to cover any event that might lead to a loss of carbon sequestration, such as natural disasters (for example, wildfires, storms, extreme meteorological events, etc..), diseases or pest outbreaks, financial risks related to the operators. The buffer pool is usually established at the outset of a project, and it is managed by the certification scheme or a third-party administrator. The carbon units in the buffer pool are not sold or traded but rather held in reserve to guarantee the validity of the carbon units issued by the project. The CRCF units generated by carbon farming activities, in fact, are temporary units that will expire after the end of the monitoring period.

A risk assessment for reversal shall be conducted to determine the size of the buffer pool and guide the development of risk mitigation strategies for each project. Risk assessment of reversal is the process of evaluating the likelihood and potential impact of events that could lead to the release of carbon already sequestered by the end of the monitoring period (Box 1 for the definition).

The buffer pool and risk assessment are key in carbon credit schemes as they contribute to the mitigation and permanence of carbon units in several ways:

- By setting aside a reserve of carbon units, the buffer pool ensures that the project can account for any potential reversals or losses of carbon sequestration, thereby maintaining the permanence of the units issued.
- The risk assessment helps to identify potential risks and develop strategies to mitigate them, reducing the likelihood of reversals or losses of carbon sequestration.
- The use of a buffer pool and risk assessment demonstrates a project's commitment to avoid the carbon reversals, increasing the credibility of the project and the credits it issues.
- By promoting sustainable land use and management practices, carbon credit projects can help to mitigate the risks associated with land use changes and land management practices and ensure the long-term sequestration of carbon.

However, a few concerns were raised on some of the methodologies for buffer pools calculations, resulting in a potentially not accurate assessment of the risks associated with carbon sequestration projects. To ensure the integrity and effectiveness of carbon credit systems, it is essential to develop science-based approaches to risk assessment and buffer pool size quantification, incorporating the latest research and data on disturbances, carbon sequestration risks and uncertainties.

This policy brief aims at providing recommendations for the development of science-based risk assessment and buffer pool quantification. First, we present some of the established approaches for buffer pool size quantification in carbon credit schemes; second, we provide suggestions and concrete examples on the development of a science-based buffer pool; and third we discuss current limitations and research gaps. By doing so, we aim to contribute to the establishment of a reliable buffer pool calculation methodology that accurately accounts for potential risks and supports the long-term permanence of carbon units issued for two specific carbon farming activities: afforestation and agriculture.

## Current approaches for calculation of risk and buffer pool size

Various methodologies are currently available in different certification schemes for afforestation and agriculture sector projects. This section provides an overview of the current methodologies and highlights their current limitations and uncertainties.

**Afforestation**. The IPCC Tier 1 and Tier 2 approaches use default values and look-up tables to estimate carbon sequestration and leakage risks. Verra's Verified Carbon Standard (VCS) methodology uses a risk assessment framework to evaluate the likelihood and impact of risks such as fire, pests and disease, and requires project developers to conduct a risk assessment and develop a risk management plan. Gold Standard's Afforestation/Reforestation methodology employs a risk assessment matrix to evaluate risks and determine buffer pool size and requires project developers to conduct regular monitoring and verification to ensure that the project is meeting its emissions reduction targets. The UNFCCC's Clean Development Mechanism (CDM) methodology uses a leakage risk assessment framework to evaluate the risk of leakage, which is the increase in greenhouse gas emissions outside the project boundary as a result of the project, and requires project developers to develop a leakage risk assessment and management plan. The Label Bas Carbone (LBC) assesses the risk associated to fire, pests, and diseases, and assigns a risk score to each project to determine the size of the buffer pool. All these methodologies also consider factors such as project location, tree species, and management practices to estimate carbon sequestration rates and risks. The established buffer pool from these methodologies typically ranges from 10% to 30% of the total carbon units issued by the project.

**Agriculture**. Current methodologies for estimating the buffer pool size and risk of reversal for soil organic carbon removals and greenhouse gas emissions in the agriculture sector include the IPCC Tier 1 and Tier 2 approaches, as well as methodologies developed by Verra, Gold Standard, and the Soil Carbon Initiative. These methodologies use a combination of default values, look-up tables, and probabilistic approaches to estimate carbon sequestration and leakage risks and are applied to both soil organic carbon removals and agricultural land management projects.

Recent studies have raised concerns that some methodologies may underestimate the required buffer pool size, suggesting that current buffer pools may be inadequate (Haya, et al. 2023, Anderegg et al., 2025). To address this issue, there is a pressing need for more scientific research, modelling and data collection to inform the development of robust buffer pools and risk assessments. The growing demand for carbon credits and the emergence of carbon farming initiatives underscore the urgency of this research agenda. A comprehensive evaluation of current buffer pool methodologies and the development of new, evidence-based approaches are essential to ensure the integrity and effectiveness of carbon credit markets. This will require sustained investment in research and development, as well as collaborative efforts among stakeholders to share data, expertise, and best practices, ultimately informing policy decisions with robust scientific evidence.

**Figure 1 – Soil organic carbon (SOC) risk framework. based on the exposure-hazard-vulnerability risk concept. SOC under agricultural land use is considered exposed. Vulnerability, the mineral-associated organic carbon (MAOC) saturation, determines the magnitude of the exposure. The hazard (soil organic carbon changes, ΔSOC) is the integrated effect of climate change and land use that acts on exposed SOC.**


*Source:* from from Breure et al., 2025.

## Towards science-based EU-wide risk assessment and fuffer and buffer pool calculations

In this section, we provide an EU-wide example for the quantification of risk of reversal and the carbon farming project's contribution to the buffer pool size. Moreover, we provide some general guidelines for the development of methodologies. We note that, while afforestation and agricultural farming activities are both land-based solutions, their respective risk methodology differs substantially for the nature of the carbon pools involved. The accumulation of living biomass in trees can be drastically lost upon a disturbance event, while the soil organic carbon pool is much more resilient and less dependent to a single event.

### Agriculture and soil organic carbon removals

Currently there is not a consolidated framework to assess the risk of soil organic carbon (SOC) reversal, taking into consideration that SOC has an intrinsic resilience due to different protection mechanisms. Therefore, the methodology is following the concepts proposed in the recent scientific paper of Breure et al., (2025), adapting the IPCC risk framework into a SOC risk index. Under the IPCC definition, the risk is based on the interaction of three factors: hazard, exposure, and vulnerability. For SOC, these concepts are adapted as following:

- Exposure: the SOC stock in the agricultural mineral soils.
- Hazard: climate and anthropogenic-related effects on SOC that are often very difficult to be disentangled. For this reason, the rate of SOC changes in the decade preceding the beginning of the project is considered a good proxy of drivers affecting the carbon cycle in soils.
- Vulnerability: the level of carbon saturation given by the ratio between the mineral-associated organic carbon (MAOC) over its maximum capacity that a given soil can potentially store. The MAOC is a fraction of carbon more protected but, approaching saturation, the organic carbon tends to accumulate in less protected pools and becomes more vulnerable (Lugato et al., 2021; Georgiou et al., 2022).

National or European soil inventory such as LUCAS soils, can be used to calculate SOC change (Hazard) and the saturation with pedo-climatic cluster (Vulnerability) if soil fractionations are done (see Breure et al., 2025). This can lead to defining four SOC risk classes to which a buffer pool can be attributed.

**Table 1 – Definition of the risk level based on soil organic carbon (SOC) changes (hazard) and effective saturation (vulnerability).**

| Risk | SOC change | Saturation on % | Buffer % |
|---|---|---|---|
| Very low | ≥0 | < 68 | 2 |
| Low | ≥0 | ≥ 68 | 4 |
| Moderate | <0 | < 68 | 6 |

*Source:* JRC own calculations

## Afforestation

Here, we propose an EU-wide methodology to assess the risk of reversal of afforestation projects, and the associated buffer pool. The methodology is based on a combination of state-of-the-art Earth Observation datasets and modelling approaches.

The methodology involves two steps (Figure 2). First, the assessment of risk of reversal, which uses two different products: (1) the tree species current and future suitability for afforestation projects, and (2) the characterization of disturbance regimes (return period and intensity of disturbance) for main forest types (broadleaf, needleleaf, and mixed forests). Second, the calculation of the buffer pool size for the main forest types in the EU given the disturbance regime. The methodology uses a range of datasets, including the European Forest Disturbance Atlas (Viana-Soto and Senf, 2025), Copernicus Land Monitoring Service High Resolution Layer Forest Type, the Biomass map of the European Space Agency – Climate Change Initiative (ESA-CCI) (Santoro and Cartus, 2025), and the EU-Trees4F dataset (Mauri et al., 2022).

**Risk Assessment.** The risk assessment is carried out over an area delimited with hexagons (35km radius). The first step in the risk assessment is evaluating the present and future (currently up to 2065) climate suitability of the species planned in the afforestation. The species suitability assessment is based on the climate scenario RCP 4.5. In our methodology we use the EU-Trees4F dataset of current and future potential tree species suitability distributions (Mauri et al., 2022), but other datasets have been developed recently. The second step is the characterization of the disturbance regime and involves combining the European Forest Disturbance Atlas with the forest type map to compute the current disturbance risk per forest type, and the ESA-CCI biomass data to assess the intensity of disturbances, which is the biomass lost for each disturbance. The risk classes are defined by the return period of disturbance events, being classified as ”low” risk (return period above 30 years), “high” risk (return period below 15 years), and “medium” risk (return period between 15 to 30 years). The intensity of disturbance is then used to calculate the buffer pool.

As a result, an example of the disturbance regimes is presented in Figure 3. We found that 14, 11, 24% of the European forests are are in the high, medium, and low risk category as defined above, respectively. The forest area in the medium and high-risk category is higher for needleaf forests than for broadleaf forests.

The dataset for the risk assessment is available in the Joint Research Centre (JRC) data catalogue[1].

**Buffer Pool Size Calculation.** The buffer pool is calculated for each hexagon and forest type given the disturbance regime characterised as described above. For each hexagon and forest type, a forest growth model based on a Gompertz function is used to simulate the forest growth without disturbance, which is hereafter as referred as ‘reference run’. Using the disturbance frequency (disturbance event return period) and intensity (biomass loss) distribution, it is possible to simulate an ensemble potential disturbance time series (500 time series) and perturb the ‘reference run’. Then, the size of the buffer pool is calculated as 1 - the mean of ratio between the cumulative stand’s biomass growth calculated under the 500 disturbance regimes and the potential growth as defined by the reference run. The uncertainty of the buffer pool is calculated as is standard deviation. The buffer pool size is taken as the mean plus the standard deviation of this unrealised biomass growth due to disturbance in each hexagon. The granular data are distributed in the JRC data catalogue[1].

For this policy brief, we aggregated the granular buffer pool size, and we report for each main forest type (broadleaf dominated forests, needleleaf dominated forests, and mixed forests) the average buffer pool within each class and bioclimatic regions. The resulting buffer pool range is reported in Table 2.

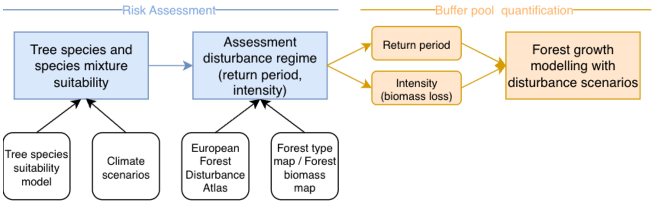
[1] https://data.jrc.ec.europa.eu/collection/id-00445

**Table 2** – Aggregation of the granular buffer pool for each forest type and return period indicator (reported as mean + standard deviation).

| Forest type | Return period class | | |
|---|---|---|---|
| | Low | Medium | High |
| Broadleaf | 15% | 28% | 66% |
| Needleleaf | 19% | 39% | 77% |
| Mixed forests | 19% | 30% | 69% |

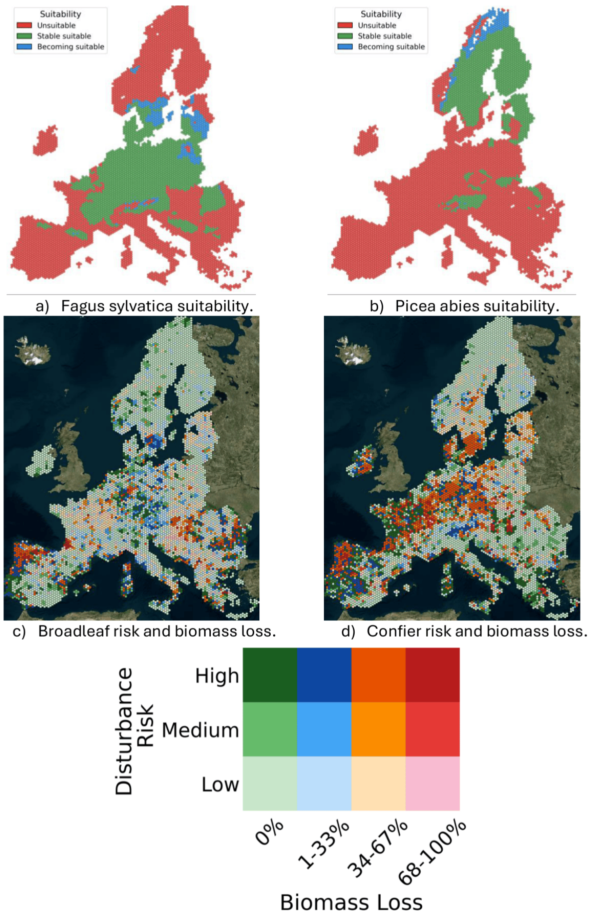
*Source:* JRC own calculation

**Figure 2** – Schematic representation of the workflow for risk assessment and buffer pool size calculation.




*Source:* Joint Research Centre

**Figure 3** – Example of tree species suitability maps and risk assessment for European forests




*Source:* Joint Research Centre

The current approach for afforestation has few limitations.

First, currently the disturbance regime is static as only recently reliable EU-wide future disturbance scenario were published (Grünig et al., 2026). Moreover, Horizon Europe projects are now developing more of such scenarios, and the JRC is developing a natural disturbance scenario.

Second, the use of hexagons can be a simplification in areas with complex topography. For such cases, an operator-based risk assessment could be preferrable.

Third, genetic variability and provenance is not considered in the current tree suitability modelling. For such cases an operator-based tree species or tree species suitability could be preferrable if the operator intends to use provenances or tree species sourced from southern nurseries or more southerly provenances that can guarantee climate resilience, and offer better tolerance to heat, drought.

Finally, it would be beneficial to test the risk and the buffer pool in afforestation projects already existing, including the ones that failed.

## Limitations and way forward

Despite the availability of the methodologies developed by the different schemes, and few novel methodologies based on latest research, including the ones suggested here, there are still limitations and uncertainties associated with quantifying buffer pool size and risk assessment.

These include:

- Lack of data and research: Limited data and research on future disturbance scenarios, vegetation and soil organic carbon fractions and temporal changes and leakage risks in different regions and ecosystems.
- Methodological uncertainties: Uncertainties associated with different methodologies and assumptions, in particular related to remote sensing and models.
- Spatial and temporal variability: Carbon sequestration and leakage risks can vary significantly across different spatial and temporal scales, and therefore the estimate of the buffer pool can be affected by the scale of the information that is used for the calculations. Moreover, for the specific case of afforestation, the genetic variability of tree species can affect dramatically the suitability of the species. For this reason, a project specific risk assessment related to

the species suitability and the use of certain provenance is suggested.

- Non-additionality, leakage risks, and missing risks: Risks that projects may not be additional (i.e., would have occurred anyway) or may lead to leakage (i.e., increased emissions elsewhere). Additional risks, such as the financial, are not currently included.

In order to overcome such limitations, the JRC is currently working, first, to implement new scenarios of biomass and natural disturbances from Horizon Europe projects and second, to develop new approaches for modelling carbon sequatration from forests and agriculture land and generate novel natural disturbance scenarios.

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